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Improvements to the Space Shuttle's External Tank

As NASA prepares to return the Space Shuttle to flight, the Shuttle's External Tank Project Office is assessing the design of the tank's Thermal Protection System, or TPS, and examining any areas where the tank's foam insulation, a component of the tank's Thermal Protection System, has the potential to be lost. The focus of this effort is to minimize any debris the tank could potentially generate, and is one of the recommendations made by the Columbia Accident Investigation Board following the loss of the Space Shuttle Columbia and her crew.

The External Tank is the "fuel tank" for the Shuttle's Orbiter; it contains the propellants used by the Shuttle's Main Engines. It is also the only component of the Space Shuttle that is not reused. Approximately 8.5 minutes into a Shuttle flight the tank – its propellant used -- is jettisoned and disintegrates over a remote part of the ocean. Because the tank is not retrievable, NASA's engineers are unable to confirm by inspection how the tank's insulation performed during ascent. Instead, they must rely on testing, computer analysis and video and photographic imaging to determine if there is a possibility of foam shedding during launch.

The External Tank Project Office is re-evaluating the tank's thermal protection and the potential for debris, through testing and analysis of some of its components, including areas that could be prone to foam loss such the protuberance airload ramps and the liquid hydrogen tank/intertank flange closeout area and an area that is prone to ice, the liquid oxygen feedline bellows. These tests and analyses are expected to determine the potential for foam loss in these areas and possible ways to improve the overall safety of the External Tank for the Space Shuttle system.

The project office is also reviewing how the thermal protection system is applied to the tank and examining new techniques that will allow the foam to be tested without damaging it.

Liquid oxygen feedline bellows

The liquid oxygen feedline bellows is part of the liquid oxygen feedline assembly that extends externally along the right side of the liquid hydrogen tank, up to and within the intertank, which joins the liquid hydrogen and oxygen tanks, and then to the aft dome, or bottom, of the liquid oxygen tank. The line is approximately 70 feet long and about 17 inches in diameter. The three liquid oxygen feedline bellows are joints that allow the feedline to move, or flex, when the tank is assembled and during installation of the feedline. The joints also allow the lines to adjust as the liquid hydrogen tank is filled and permit the line to adapt to the forces generated at liftoff. The feedline is insulated with foam. However, because the bellows must allow for movement, they are not insulated.

The current configuration of the bellows allows ice to form during prelaunch tanking of the External Tank when moisture in the outside air contacts the cold surface of the uninsulated bellows; because the bellows are not insulated, they are subjected to the minus 423 degree temperature of the liquid hydrogen tank. Though there have been no reported losses of foam insulation from this area of the tank, photographs taken prior to launch indicate that ice does form. If ice in this area dislodged during liftoff, it could potentially damage the Shuttle system.

Therefore, the project office is redesigning the bellows to eliminate the potential for ice debris and will retrofit the new design to the External Tank. Design concepts under consideration are a flexible heated bellows boot, or protective covering; use of heated gaseous nitrogen (GN_2) or gaseous helium (GHe) to purge the bellows prior to launch; and incorporating along with the use of a coating material that sheds water. These concepts are intended to either prevent ice formation on the bellows or to contain the ice during ascent.

Protuberance Airload Ramps, or PAL Ramps

The External Tank's protuberance airload ramps, known as PAL ramps, are foam ramps designed to reduce adverse aerodynamic loading, or forces, on the tank's cable trays and its pressurization lines during launch. One of those ramps is near the top of the liquid oxygen tank, close to the nose cone; the other is below the intertank, near the top of the liquid hydrogen tank.

Presently, the three redesign options being evaluated are eliminating the ramps, reducing the size of the ramps to "mini" ramps, or building a "fence" to protect the cable trays and lines. The project office will continue to evaluate the redesign candidates and, after completing a comprehensive testing and analysis program on the options, select one for implementation.

Liquid Hydrogen Tank/ Intertank Flange

The External Tank's intertank is the structural connection that joins the liquid hydrogen tank and the liquid oxygen tank. Flanges, which are joints that function like a tab or a seam on a shirt, are affixed at the top and bottom of the intertank so the two tanks can be attached to the intertank. The liquid hydrogen tank flange is at the bottom of the intertank. Once the two tanks are joined to the intertank, the flange is insulated with foam.

There is a history of foam loss from this area during liftoff -- foam divots, or pieces, from this area have typically been less than 0.100 pound and considered a maintenance issue for the Orbiter. Therefore, the External Tank Project Office is conducting tests to determine why foam insulation in this area sheds. One modification being considered is to continually purge the intertank flange crevice with heated gaseous nitrogen or helium to prevent the formation of liquid nitrogen in the joint area of the LH2 tank to intertank. Although not proven, this is considered a possible contributor to foam loss. Another modification under consideration is to enhance or improve the foam application procedures on the flange area.

TPS (Foam) Verification and Nondestructive Inspection of Foam

In response to the Columbia Accident Investigation findings, the External Tank Project Office is also reassessing how the foam is both manually applied and hand-sprayed, on the tank. Using flight history, the project office has created a list of areas where such applications could later generate debris and is establishing requirements for additional quality tests for these applications. Included with this assessment is a review and update of the process controls, such as requiring at least two employees attend all critical hand-spraying applications to ensure proper processing and security.

NASA is also pursuing the development of nondestructive inspection techniques on the tank's thermal protection system. The initial focus is on manually sprayed closeout, or final, foam applications. The project office is surveying state-of-the-art technologies and evaluating their capabilities. Initially, test articles with known defects -- such as voids in the foam -- were used to determine the detection limits of the various methods. Two technologies that show promise are terahertz imaging and backscatter radiography.

The main advantage of a terahertz imager is that it does not emit any radiation, capturing pictures of the natural terahertz rays emitted by almost all objects. Occupying a portion of the spectrum between infrared and microwaves, from 10^{11} to 10^{13} Hertz, terahertz waves can pass easily through some solid materials, like walls and clothes, and can also be focused as light to create images of objects. The terahertz imaging is being developed in conjunction with NASA's Langley Research Center in Langley, Va.

Backscatter radiography was originally developed for military use at the University of Florida in Gainesville, Fla. The backscatter technique uses X-ray photons that bounce off the electrons of materials.

The External Tank Project Office is conducting more comprehensive testing on these technologies.